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The Raccoon (*Procyon lotor*) on St. Catherines Island, Georgia. 7. Nesting Sea Turtles and Foraging Raccoons

SYDNEY ANDERSON[1]

ABSTRACT

The activity of loggerhead turtles, raccoons, and other animals was studied in three months in 1979 on 9.5 km. of beaches on St. Catherines Island, Georgia. An estimated 250 clutches of eggs were laid on the island in 1979, eggs in clutches counted averaged 139 in June and 101 in July. Different beaches had significantly different amounts of activity, but no clear correlations with environmental factors emerged as probable causes. There was no conspicuous peak of activity in the two months studied. There was no indication of preference by turtles for laying at any particular time of night. Raccoon tracks were more abundant nearer areas with trees, but all parts of beaches were occupied some of the time. There was no shift in position of home ranges or activity centers of five raccoons studied by radiotelemetry between April (when no turtles were present) and the summer nesting season. In terms of energy spent versus energy required, it would probably not be worthwhile for a raccoon to forage on the beaches for turtle eggs *alone*. There are enough raccoons whose home ranges include the beach to account for observed activity, with no shift in ranges. Any one place on the beach is within the home ranges of about 10 raccoons. The number of raccoons on the island probably fluctuates between 400 and 4000, and is usually between 1000 and 2000 (on 29 km^2 of high ground and about the same area of salt marsh). We observed 23 dead turtles in 1979 and 26 in 1980. The probability that a nest will be found and disturbed by a predator is high at first and declines with time. More than half of all nests are disturbed before hatching occurs. Roughly one-third of disturbances are by raccoons, one-third by pigs, and one-third by other animals or by erosion.

INTRODUCTION

It is well known that loggerhead turtles (*Caretta caretta*) nest on the beaches of Georgia, and of St. Catherines Island in particular, and it is known that raccoons dig up turtle eggs and eat them. However, there are few data on how many nests are prepared by turtles on the island, what parts of the beaches the turtles use, what times are favored for nest consturction, how many nests are found and damaged by raccoons or other preda-

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tors, and whether raccoons change their foraging strategy when nesting begins. In 1979 the first quantitative survey was made in order to clarify these ecological relationships on the island. In 1980 a few days of additional observations were obtained.

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I was greatly assisted also by graduate students Joerg-Henner Lotze and Gil Weldon Willis of the City University of New York, and by my wife, Justine Anderson.

Some of the equipment used was purchased with funds from Jack Rudin of New York and the Blakemore Fund.

METHODOLOGY

Major techniques for our study of raccoons included live-trapping, marking, release, and recapture; preparation and observation of special trackways; and radio telemetry.

The attachment of a small radio transmitter in a collar on a raccoon enables the investigator to find the animal and to record its position and activity by using a small portable radio receiver and directional antenna. This technique makes it possible to study the place and time of activity during the day or night (Anderson and Hudson, 1980), the overall home range (Lotze, 1979), and changes with season and other environmental factors, such as the availability of turtle eggs or other food sources. Collars were put on five adult raccoons, three males and two females, in late March and early April. These animals were monitored in April, June, and July, as long as possible, in order to compare their areas of activity in these different months (April before the turtles nested and June and July while nesting progressed).

Trackways of two types were prepared. Firstly, 10 trackways of cleared, tilled, and raked soil or sand, each 1 by 5 m., were prepared at intervals along 2.8 km. of Jungle Road (see fig. 1 for this and other places mentioned hereafter), which lies inland 200 to 300 m. from the beach. Secondly, continuous trackways were prepared on the beach by dragging a special rake near the high tide line, or reading the trails in the sand naturally cleared of tracks by rains or the tides at times known to us. Most of the North Beach (4 km.) and most of the South Beach (5.5 km.) were examined daily for trails made by raccoons, pigs (*Sus scrofa*) and other mammals, as well as for any signs of turtles. We thought that by comparison of relative numbers of trails on inland and beach trackways and in the two seasons (before and during turtle nesting) we might detect some shift in where raccoons were spending their time.

We trapped with 50 live-traps along Jungle Road and South Beach Road. We hoped, thereby, to estimate the number of raccoons frequenting the area near the beach.

Major techniques for study of sea turtles were daily and nightly trips up and down the beaches and the recording of information on turtle trails or "crawls," nests, and turtles seen alive or dead. Sometimes several trips were made in one night, the number depending chiefly on availability of equipment, the weather, and the tidal cycles. It was not possible, because of high tides and dead trees on some parts of the beaches, to intercept and observe more than a few of the emerging turtles.

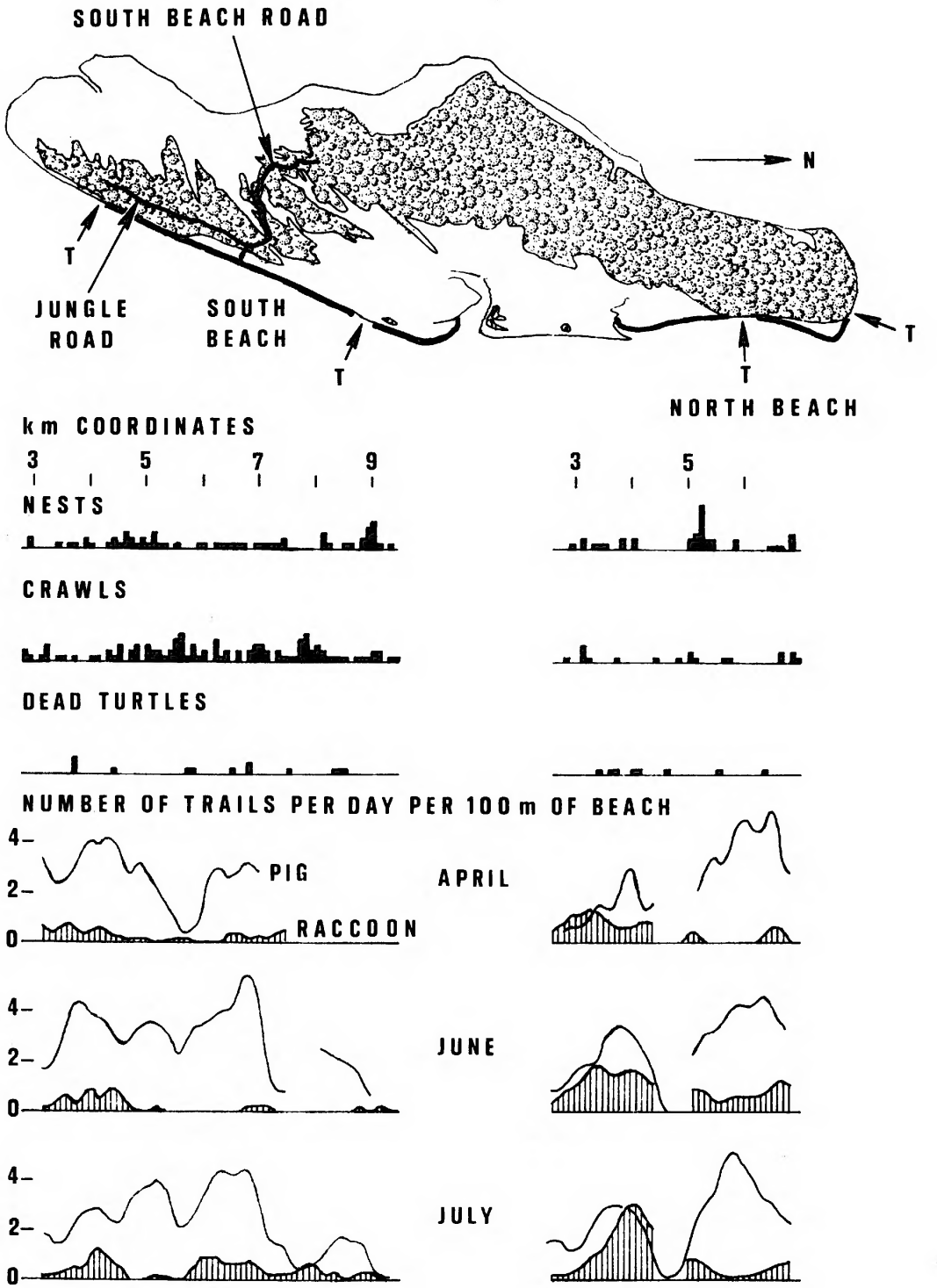

FIG. 1. Map of St. Catherines Island showing study areas and amounts of activity of turtles, pigs, and raccoons on different parts of the beaches. Forests are indicated, other areas are chiefly salt marshes and (along beaches) sand dunes. Dead trees on beaches limited our access at points labeled T. Intensively monitored beaches and two roads along which traps were set are shown by dark lines.

RESULTS

The results are presented as a series of questions and answers.

How many clutches of sea turtle eggs were laid on St. Catherines Island in 1979? Firstly, the only species of sea turtle known thus far from the island is the loggerhead, *Caretta caretta*. We did watch for other species, but saw none. Secondly, a turtle does not excavate a nest every time it crawls on the beach, and not all excavations are completed and laid in, so it is not a simple task to recognize a nest. Some crawls, including well disturbed patches of sand resembling nesting areas, do not include any eggs and some seemingly haphazard surface features on a crawl may be found over eggs. We confirmed 58 nests by observing the turtle laying, by finding shells of eggs or intact eggs excavated by predators or erosion, or by carefully digging enough to see the first egg. An additional 38 nests were suspected, although not confirmed. An additional 124 crawls not thought to involve nests were recorded. Thus we observed a total of 220 turtle crawls or the consequences thereof (a nest first detected when a predator dug it out). This was on 10.7 km. of sandy beaches, about 63 percent of all 17 km. of such beaches on the island, and in the months of June and July. Some beaches were not regularly explored because fallen trees, tidal inlets, or other factors made it inconvenient to do so in the available time. Assuming that these beaches had the same frequency of nesting as those explored, and assuming that May and August had only 65 percent (an arbitrary figure) of the June and July values, and extrapolating; the total of clutches of loggerhead turtle eggs laid on St. Catherines Island in 1979 was about 250.

How many eggs are in a clutch? The average number of eggs in clutches counted as they were laid was 139 (n = 3) in June and 101 (n = 5) in July. The average number of egg shells counted at nests raided by predators was 41.9 (n = 21) in June and 41.2 (n = 8) in July. The count is actually an estimate because shells frequently fragment and pieces scatter. The number of shells varied from 15 to 100. In some cases the entire clutch was destroyed at one time and in a few cases the same nest was raided on more than one day. In some cases (the number is not known) only part of the clutch was destroyed, a conclusion based both on the differences in numbers of eggs recorded above and the observation that eggs are removed from some nests on more than one occasion.

Are certain parts of the beaches favored more than other parts by emerging loggerhead turtles? Examination of figure 1 shows where activity is known to have occurred. There seems to be a tendency to aggregation of nests in kilometers 94, 98, and 05, but on the whole the activity seems well scattered. Chi-square tests were used to compare observed distributions in half kilometer segments against the null hypothesis of equal probabilities in all segments. The North Beach, in comparison to the South Beach, had significantly less activity than expected under the Null Hypothesis ($\chi^2 = 12.67$, d.f. = 1, $P < .005$). The segments of North Beach differed significantly ($\chi^2 = 34.85$, d.f. = 6, $P < .005$), but those of South Beach did not ($\chi^2 = 14.50$, d.f. = 11, P about .5). In general, my preliminary hypotheses about habitat preferences of turtles have been weakened if not completely falsified by the season's data. Many additional data would be needed to detect subtler differences in turtle preferences than those indicated. There are rather gross differences between different parts of South Beach in steepness of banks, nearness of trees, and amounts of sand and debris, but these seem not to have mattered to the turtles.

When in the year are nests prepared? Data from other studies in Georgia and Florida as well as reliable although unsystematic observations over many years by the local people clearly indicate that turtles nest in the warmer months of the year and probably more in June and July than in May or August. We have one observation of a nest as early as May 10 (in 1975, found by Trudy Thomas and recorded by Dennis Harman). The peak, if there is one, in late June is not conspicuous. The activity seems scattered through the

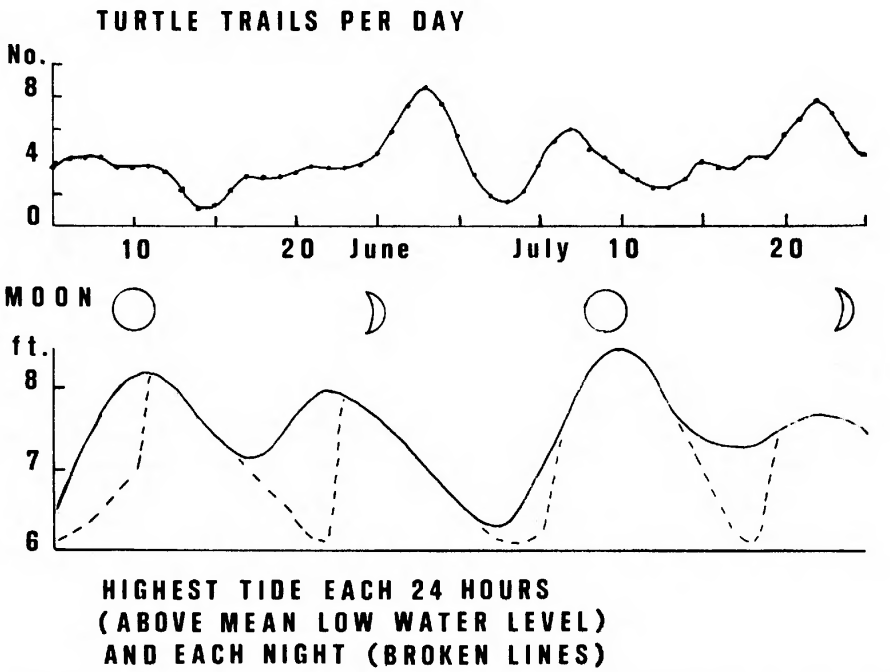

FIG. 2. Amount of sea turtle activity on 9.5 km. of beaches on St. Catherines Island, Georgia, per day in June and July 1979. Trails include both those on which the turtle nested and those on which it did not nest or lay eggs.

two months for which we have data (see fig. 2). The phases of the lunar cycle and the height of the highest high tide each day (and during the hours of darkness only, lower curve) are shown. There is no clear relationship between occurrences of especially high tides and numbers of turtle crawls. Many more data than obtained on this two-month survey would be required to examine critically other variables such as water temperature, roughness of sea, barometric pressure, cloud cover, air temperature, humidity, and precipitation on time of activity during the annual or daily cycles.

What times of night are preferred for nesting? We have so few definitely known times of nesting that it is not possible to demonstrate any significant preference for time of night. Clearly, night is preferred to daytime. The known hours of occurrence of eight layings are as follows: hour 2300, 1 nest; 0000, 5; 0100, 4; 0200, 1; 0300, 4; 0400, 3. We spent less time on the beaches searching in the early hours of darkness than in later hours. Therefore, these figures do not indicate any preference by turtles for laying at any particular time of night.

Are some parts of the beaches less used by raccoons than are other parts? When considering possible measures to reduce predation by raccoons on turtle nests, it may be important to know whether the activity of raccoons is concentrated and, if so, where. The counts of raccoon trails on the beaches provide an index to amounts of and places of activity. Figure 1 shows the relative frequencies in different months and in different parts of the beaches. In general, those parts of the beaches that are nearest forest or hammocks with trees are frequented more by raccoons than are more distant beaches. No part of the beach, however, is so distant that raccoons are not present from time to time.

Did the five raccoons studied by radiotelemetry change foraging strategy when turtle nesting began? We thought that by putting

TABLE 1
Summary of Data on Raccoons

		March April	June	July
A	Number of trap-nights (one trap set for one night)	1079	1016	682
B	Number of raccoons captured	43	12	3
C	Number of captures (includes recaptures)	48	15	3
D	Percentage of traps sprung or overturned (by pigs usually, does not include raccoon captures)	—	—	—
	First 5 days of trapping	6	24	17
	Last 5 days of trapping	49	51	22
E	Trap-nights per raccoon capture (ratio of A to C)	22.5	67.7	227.3
F	Undisturbed trap-nights per raccoon capture	16	38	189
G	Number of raccoon trails on Jungle Road trackways per day	(n = 16) 6.62	(n = 14) 2.14	(n = 10) 0.30
H	Number of raccoon trails on South Beach parallel to Jungle Road per day	7.5	7.2	8.2
I	Ratio of G to H	.88	.30	0.04
J	Size of home range in hectares			
	Procyon 1001 ♀	30	16	22
	1003 ♀	25	9	16
	1002 ♂	39	37	36
	1007 ♂	66	18[a]	—
	1006 ♂	33	—	—

[a] Only 12 locations established.

radio-collars on five animals at sites inland of the beach in April, the month before the turtle season, we might detect some movement of these raccoons toward the beach in June and July. Both of the two females were within 100 m. of the beach at least once in April and could have reached it in a few minutes at a slow walk (see fig. 3). One of the three males was also near enough to have done this. We located this male so few times that it is possible that he did go to the beach without our detecting it. The other two males were farther away from the beach than the above three animals. The centers of activity for these two were about 1.4 km. from the beach. Telemetry data indicate that there was no shift in the position of home ranges or activity centers for any of the four animals with adequate data (see table 1).

The trackway data were also collected to test the hypothesis that activity might shift to the beach when turtles arrived. Raccoon trails on the 10 Jungle Road trackways were fewer in June (2.14/day, mean for nine days) and July (0.4/day, mean for 10 days) than in April (6.62/day, mean for 12 days). Raccoon trails on the South Beach paralleling Jungle Road were about the same in June (7.2/day) and July (9.1/day) as in April (7.5/day). This suggests that the decrease in raccoon trails on Jungle Road was for some other reason than the movement of the animals to the beach.

With what we now know about the frequency of turtle nestings, we can consider the probable return to a raccoon that hunts on the beach. Assuming (1) that a raccoon might search along 1 km. of beach (that being about the extent of the home range of most raccoons on St. Catherines Island); (2) that the probability of finding a nest with eggs decreases with time, both because the eggs

in a nest may be partly or completely destroyed and because their detection becomes more difficult as original scent or other signs are removed by tide, rain, and wind, so that a nest is effectively available for only two weeks on the average (this is merely a generous "ball park" estimate for discussion), and (3) that 25 nests appear over six weeks' time on 2.5 km. of beach; it follows that the raccoon and any other raccoons whose home ranges overlap its home range (and there may be a dozen or more of these) cannot find and raid more than one nest each two days. If 10 raccoons are equally successful in finding nests, then each raccoon can obtain no more than one nest each 20 days. An interesting question is whether it would be worthwhile in terms of energy gained versus that expended, for a raccoon to walk 1 km. of beach each night to find one nest of eggs each 20 days. Probably this oversimplifies the situation. Raccoons are omnivorous and opportunistic and their searches for food on the beach yield many other things besides turtle eggs. Viewed in this way, they may well be able to afford to hunt for eggs, incidentally along with dead fish, crabs, and other delectables.

The data we have obtained do not indicate that raccoons changed their foraging strategy by moving from their normal home ranges or by spending more time on the beach. (There may be more subtle changes that we have not been able to detect). There may be enough raccoons with their usual home ranges including different parts of the beaches to provide the observed predation on turtle nests.

How many raccoons have home ranges reaching the beach? Along 2.5 km. of Jungle Road parallel to the South Beach, we trapped 22 different raccoons in April and June. Three were captured a second time. One other recapture was of an animal marked in an earlier year. Only one of the last 10 captures was a recapture, and it was of an animal caught twice in these 10 captures. Clearly there are many more than 22 raccoons in the area. Assuming that there are at least 50 raccoons and that each has 0.5 km. of beach in its usual home range, and

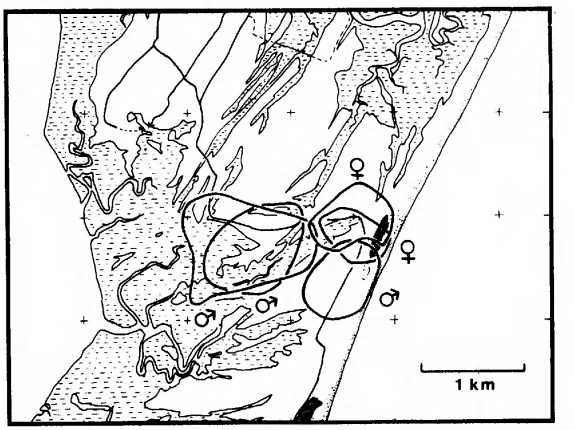

FIG. 3. Part of the south end of St. Catherines Island, Georgia, showing the home ranges of five raccoons established by radio-telemetry in 1979.

assuming a uniform distribution of ranges, then any one place on the beach will be within the home ranges of 10 raccoons. Any one kilometer of beach may have 20 raccoons present at one time or another.

How many raccoons are there on St. Catherines Island? This is not one of the questions proposed for the present research but it is the most frequently asked question by people who hear of our research, so an estimate will be ventured. First, it should be noted that populations fluctuate. Since the study of raccoons began here in 1974, the highest population may have been 10 times the lowest. The present population is intermediate. There are about 29 km^2 of habitats (mostly forest) other than salt marsh on the Island. If each square kilometer has 25 raccoons (using the estimate developed from data on Jungle Road above), then there are about 750 raccoons on the Island. The assumptions here are uncertain in various degrees. The population probably fluctuates somewhere between 400 and 4000 raccoons and is probably usually between 1000 and 2000.

How many dead loggerhead turtles wash up on the beaches of St. Catherines Island? In 1979, we observed 23 dead turtles, or parts thereof, on the beaches in June and July. Jim Evans had seen fewer than half a

TABLE 2
Summary of Data on Turtles (*Caretta caretta*)

		April	June	July
A	Dead turtles seen on beach	none	15	8
B	Average size of dead turtles (length of carapace over curve)	none	795	803
C	N (sample size)	—	4	6
D	Number of recorded "crawls"	none	115	79
E	Number of these with nests	—	70	26
F	Confirmed nests	—	32	25
G	Suspected nests	—	38	1
H	Numbers of eggs in nests counted as laid, average	—	(n = 3) 139	(n = 5) 101
I	Counted as empty shells left by predators, average	—	(n = 21) 41.9	(n = 12) 47.1

dozen before June. We saw no dead turtles in April on the beaches. The lengths of carapace measured over the curve of the shell of those that could be measured are: 610, 630, 710, 770, 800, 800, 820, 930, 960, and 970 mm. The average of these 10 is 800 m. The average of 31 measured in 1980 was 735 millimeters. In comparison, the average (n = 15) nesting turtle measured 1030 mm. (960 to 1110 range). One dead turtle had three bullet holes in its carapace and one relatively fresh turtle seemed to have had its head cut off. Otherwise, no visible evidence of probable cause of death remained. Most turtles are in advanced stages of putrefaction when first seen on the beach and the remains are not intact for long thereafter. Data from elsewhere (e.g., Unpublished report to National Marine Fisheries Service) indicate that dead sea turtles appear in numbers only after the season opens for shrimp trawling offshore. On most days in July, weather permitting, more than a dozen trawlers could be seen at work at various distances off the beaches of St. Catherines Island.

How many nests are disturbed? How soon? By what predators? Assuming that we had 78 nests under observation (60 definitely confirmed, and an estimated 18 of 36 other suspected nests), and subtracting the 10 that were disturbed at an unknown time before their discovery, we have 68 nests with known status. Their record of disturbance is as follows:

	Number	Percentage	Cumulative Percentage
Disturbed on:			
Day 1	19	28	28
2–7	5	7	35
8–30	5	7	42
>30	3	4	46
Undisturbed:	36	54	100
Total:	68	100	

The probability that a nest will be found and disturbed on any given day by a predator is high at first and declines with time. More than half of the nests are disturbed before hatching can occur. (Some of the nests recorded as undisturbed above, up to the time we ceased observations, would have been disturbed before hatching.) It should be noted, however, that many nests disturbed by raccoons will hatch some turtles later in the season (based on unpublished work by Dan Stoneburner's crew on Canaveral National Sea Shore in Florida). Since our observations did not continue to the end of the summer, most of the hatching of turtles would have been after we left. We observed no hatching up to July 26.

Tracks or other sign of animals disturbing nests and eating eggs were recorded when

possible. Numbers of nests with presumptive evidence of predation by identifiable animals were as follows:

Raccoon, *Procyon lotor*	15 nests
Pig, *Sus scrofa*	14
Birds	10
Ghost Crabs	7

Roughly one-third of nest disturbances are by raccoons, one-third by pigs, and one-third by other causes.

DISCUSSION

Observations for part of one turtle nesting season provide the first quantitative estimates on the numbers and distribution of turtle nests and what happens to them on St. Catherines Island. Other data are accumulating for other coastal islands but much more work is needed. Numbers may vary from year to year, so observations are needed over longer times.

The relationships of raccoon foraging and the success of nests of turtles need further study. As time goes by, less and less areas of beaches that are relatively undisturbed by human activity remain. Therefore, the contined maintenance of natural populations of loggerhead turtles, as well as those of the other and rarer species of marine turtles, become a matter of concern to many people. Further study is needed to assess the relative importance of predation by raccoons, pigs, and other predators or scavengers to turtle populations. The effects of human-caused turtle mortality, including drownings in nets or killings by fishermen also need further study.

Management decisions about turtle populations will be made as well as decisions about other things that will affect turtles also. In order for these decisions to have some likelihood of producing desired results and not producing undesired results, much more study is needed. Study may productively consist of carefully monitoring what happens following experimental management, whether that management involves killing feral pigs, trapping and removing raccoons, restricting shrimp boats, or protecting turtle nests with screens (just to mention a few obvious possibilities). It certainly is not obvious which alternative manipulation or which combination might be most effective (whether or not costs are taken into consideration).

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